

Multidisciplinary **A**erodynamic-
Structural **S**hape **O**ptimization **U**sing
Deformation
(MASSOUD)

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Slides are available from MDOB web site:

<http://fmad-www.larc.nasa.gov/mdob/MDOB>

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Outline

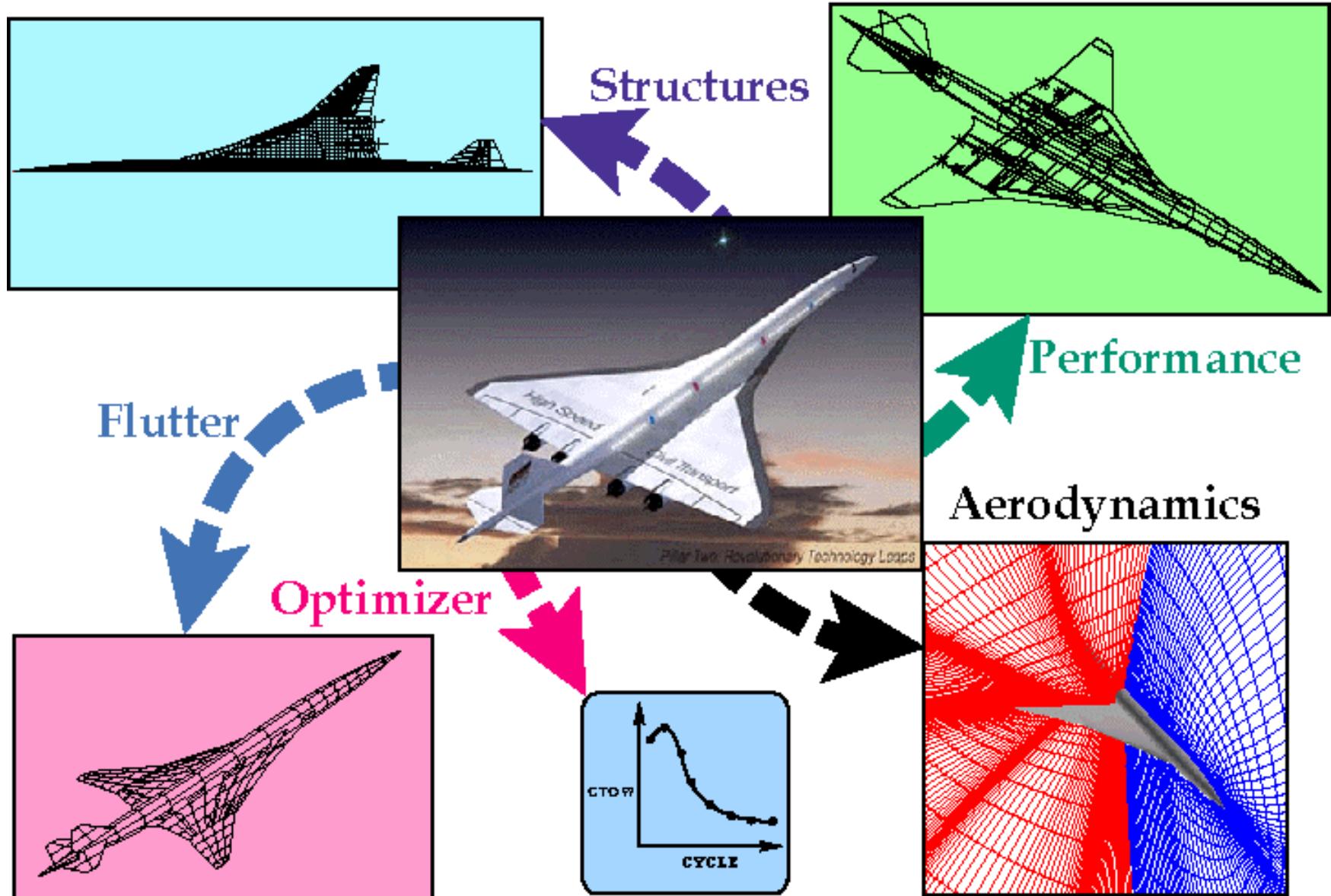
- Motivation
- Available techniques
- MASSOUD
- Results
- Summary & future work

Motivation

MDO for preliminary design phase:

- Has complex models with many details
- Requires rapid and automatic grid generation tools
- Includes high-fidelity analysis tools (e.g., CFD and CSM)
- Involves shape optimization
- Requires consistent shape parameterization across all disciplines

Multidisciplinary Shape Parameterization

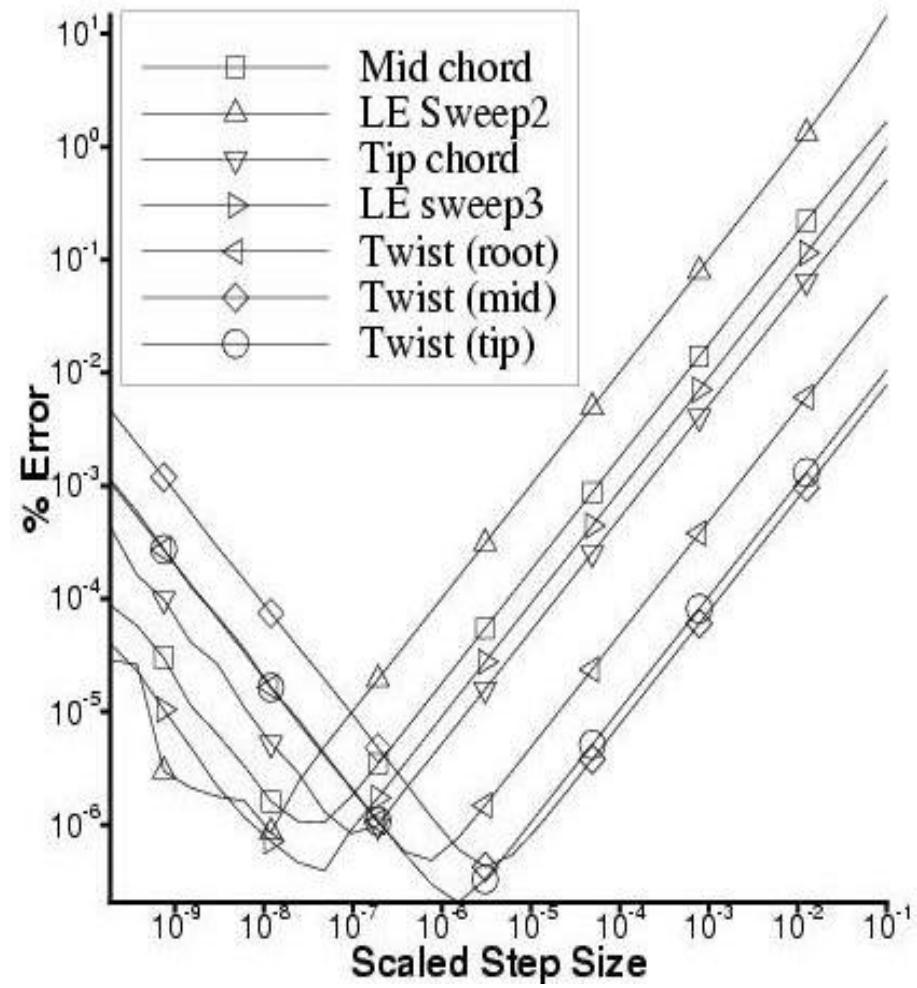
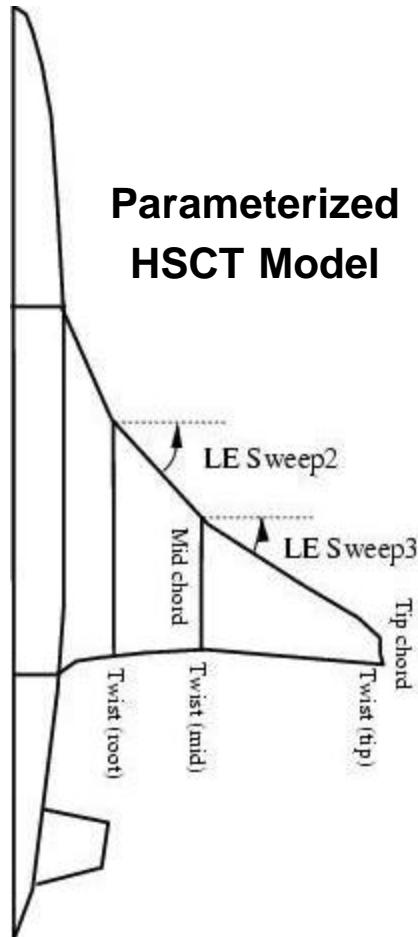


Desired Characteristics of Shape Parameterization

The shape parameterization must:

- Be consistent across all disciplines
- Be automatic (automatic grid tools are not available for all disciplines)
- Have a short implementation cycle time
- Provide a compact set of design variables (10s vs. 1000s)
- Provide sensitivity derivatives (preferably analytical, or accurate finite-difference approximation)

Finite-Difference Approximation Error for Sensitivity Derivatives



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Techniques for Shape Parameterization

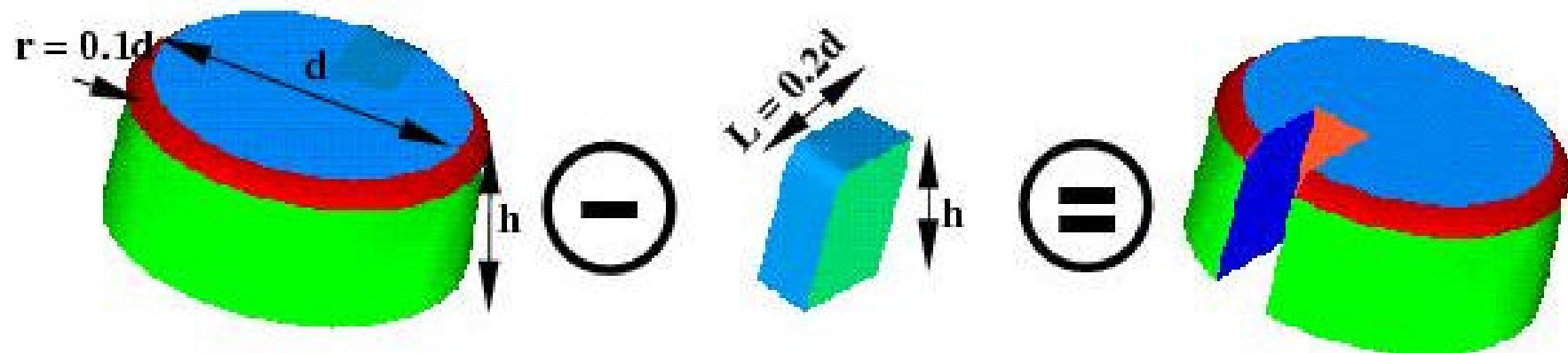
- **Basis vector** (geometry changes are represented by a set of vectors)
- **Partial differential equation** (geometry is represented by PDE)
- **Discrete** (grid points are used as design variables)
- **Analytical** (geometry changes are represented by analytical functions)
- **Polynomial and spline** (geometry is defined by polynomial and spline representations)

Techniques for Shape Parameterization (cont.)

- CAD (based on commercial feature-based solid modeling CAD systems)
- Domain element (based on macro elements)
- Free form deformation (based on a computer animation algorithm)
- MASSOUD (based on advanced computer animation algorithms)

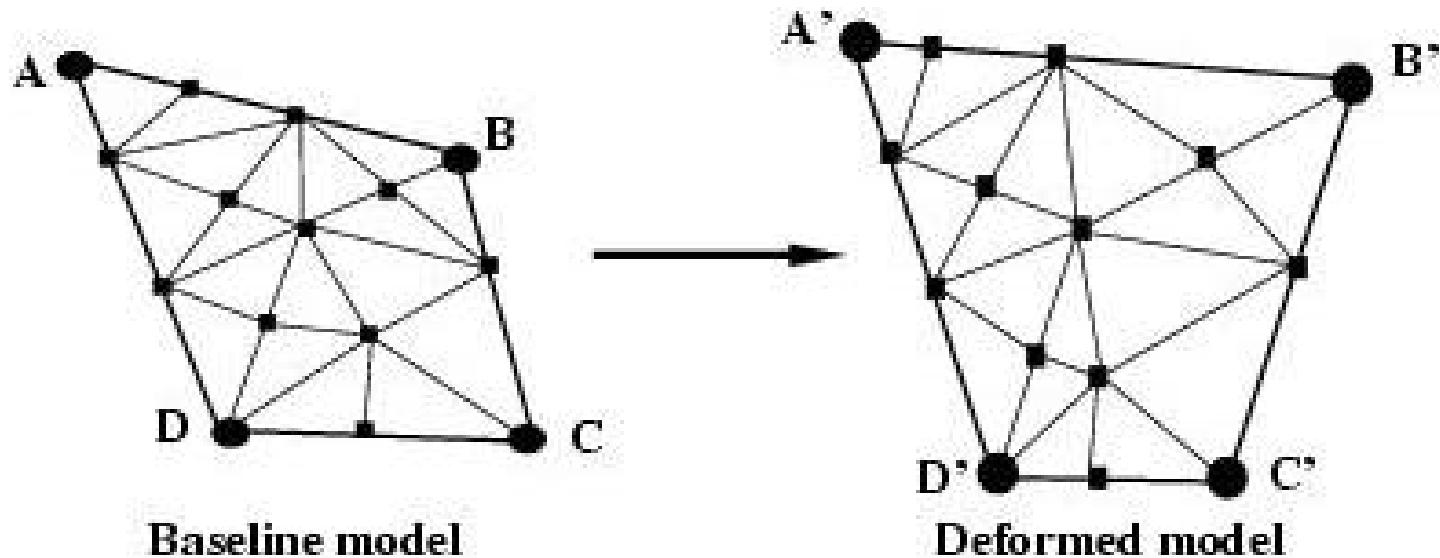
Shape Parameterization Using Feature-Based Solid Modeling CAD

- Based on Boolean operations and dimension-driven objects
- Uses simple top-down approach with high-level geometric constructions
- Uses topologically complete geometry (solids)
- Design changes are not time consuming



Domain Element Technique

- Based on macro elements
- Simple to implement
- Avoids grid generation by deforming the baseline grid

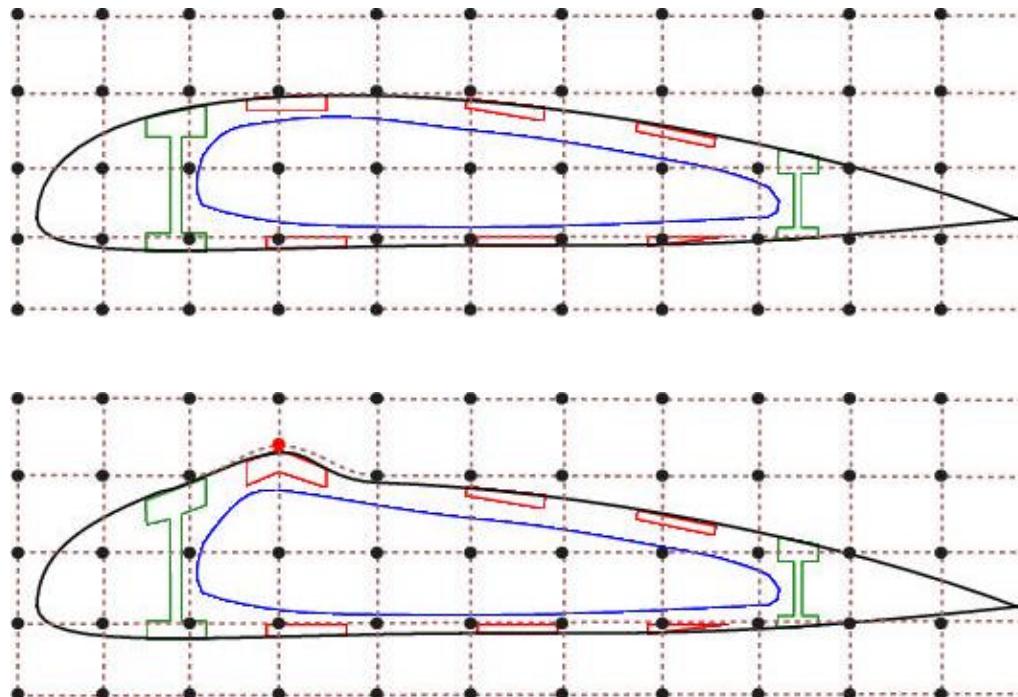


Design Variables: $(X, Y)_{A, B, C, D}$

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Free-Form Deformation Technique

- Based on algorithm used in computer animation
- Avoids grid generation by deforming the baseline grid

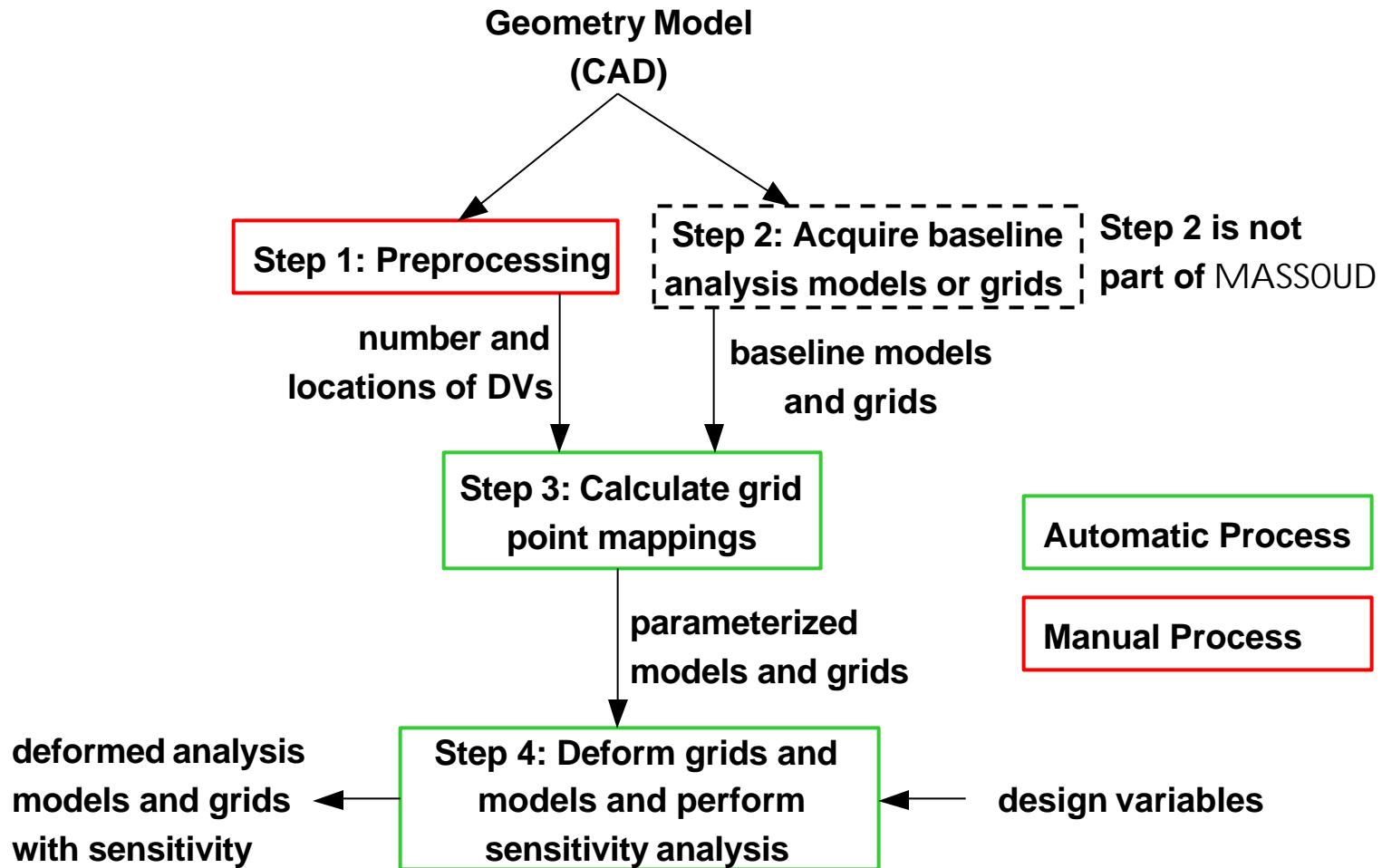


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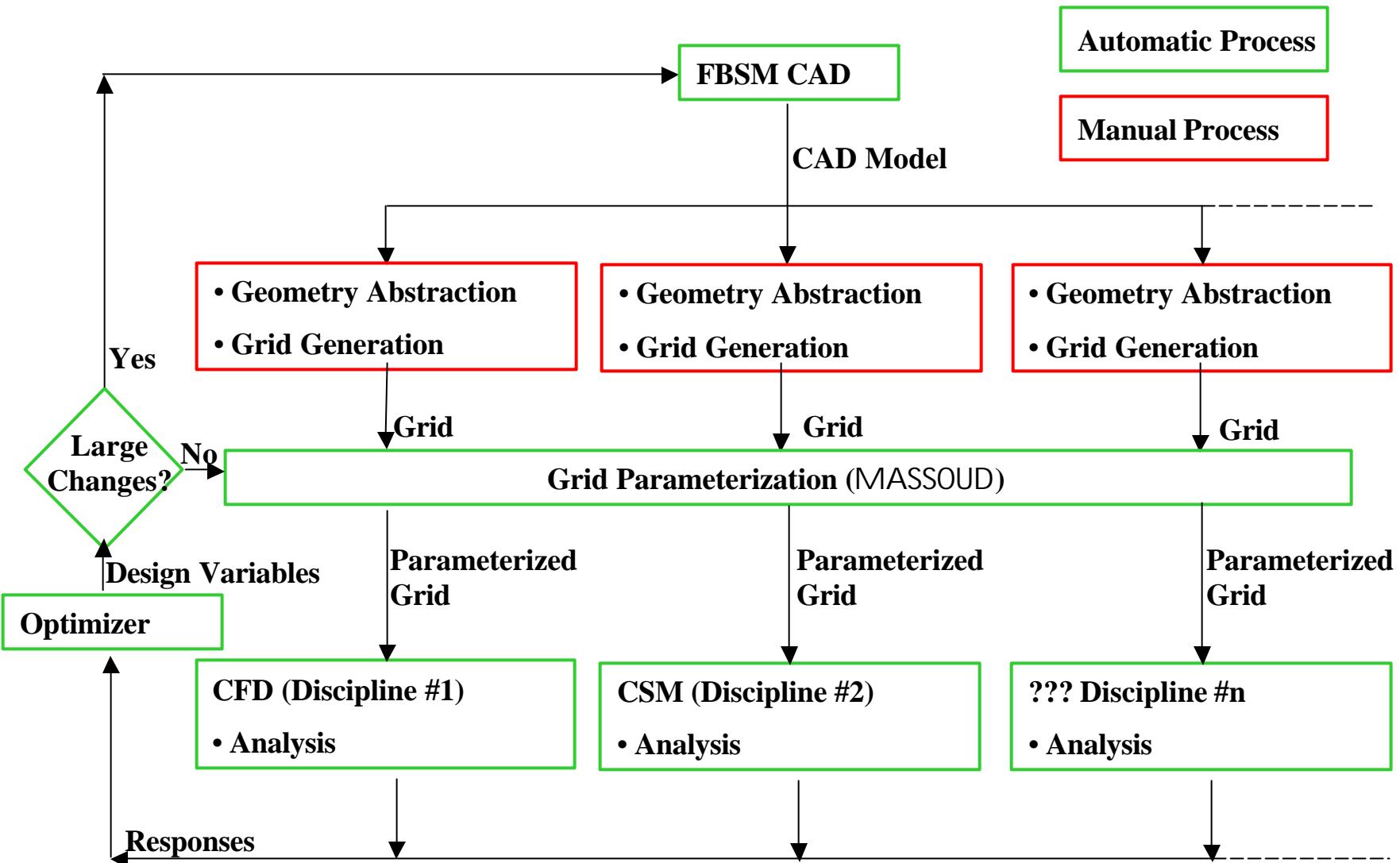
Multidisciplinary Aerodynamic-Structural Shape Optimization Using Deformation (MASSOUD)

- Uses advanced soft object animation algorithms for deforming grids
 - Nonlinear global deformation (twist and dihedral)
 - NURBS surface (camber and thickness)
 - Free-form deformation (planform)
- Parameterizes the discipline grids (avoids manual grid regeneration)
- Parameterizes the changes in shape, not the shape itself (reduces the number of design variables)

MASSOUD Process for High-Fidelity Shape Parameterization

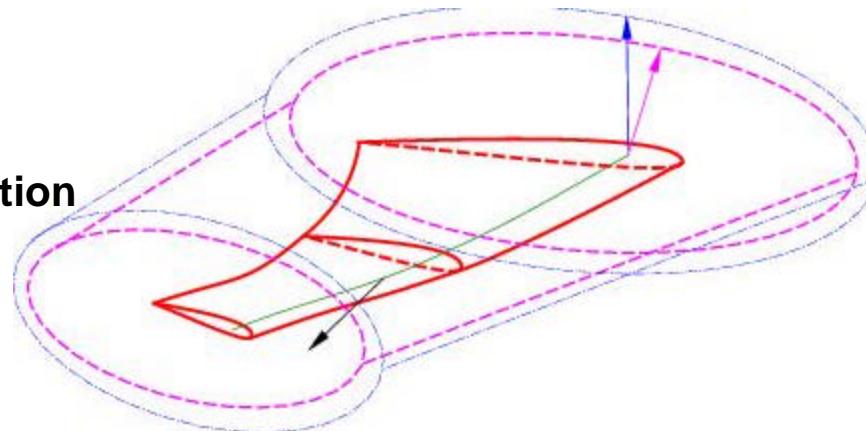


High-Fidelity Shape Optimization Process

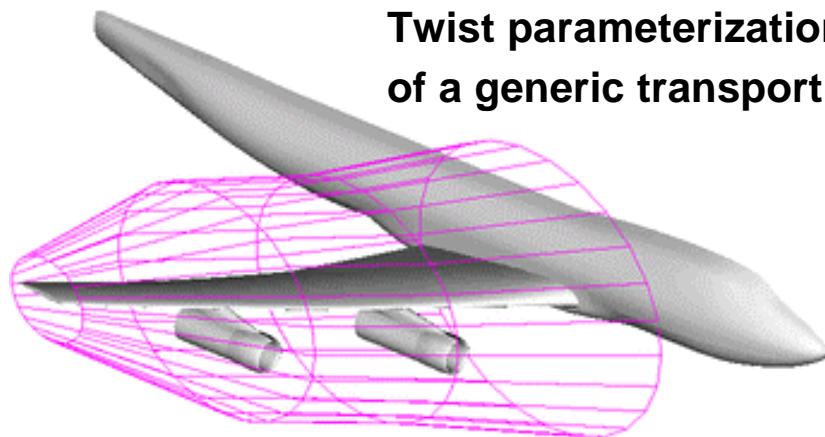


Twist and Dihedral (Nonlinear Global Deformation)

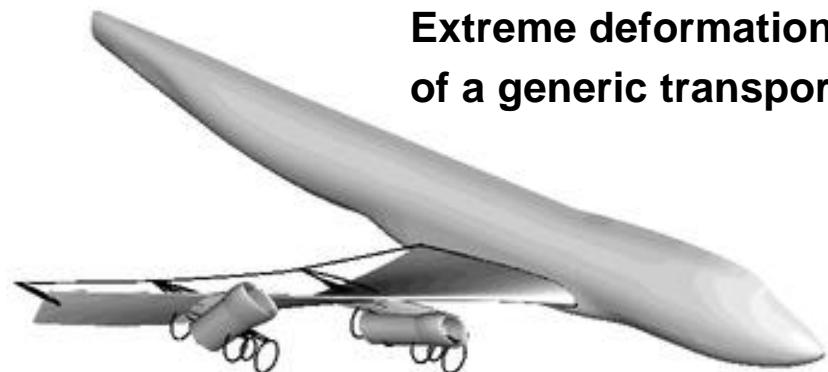
**Twist parameterization
of a generic wing**



**Twist parameterization
of a generic transport**

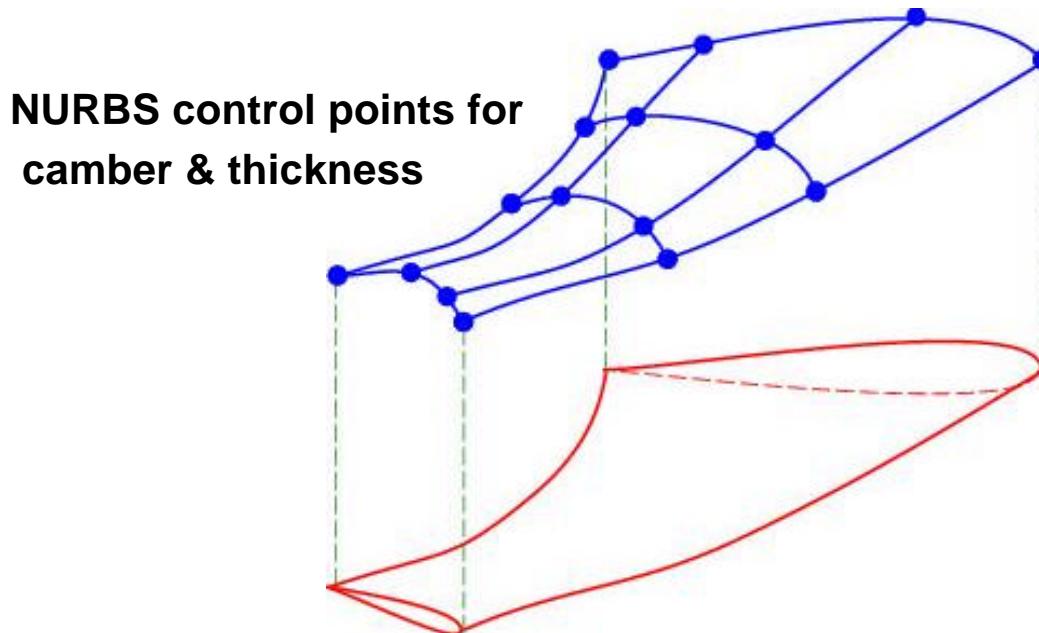


**Extreme deformation
of a generic transport**

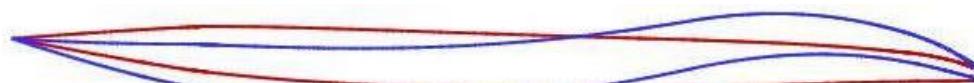


Camber & Thickness

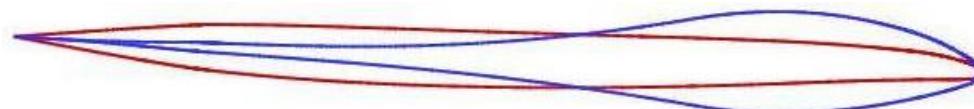
(NonUniform Rational B-Spline (NURBS))



Camber



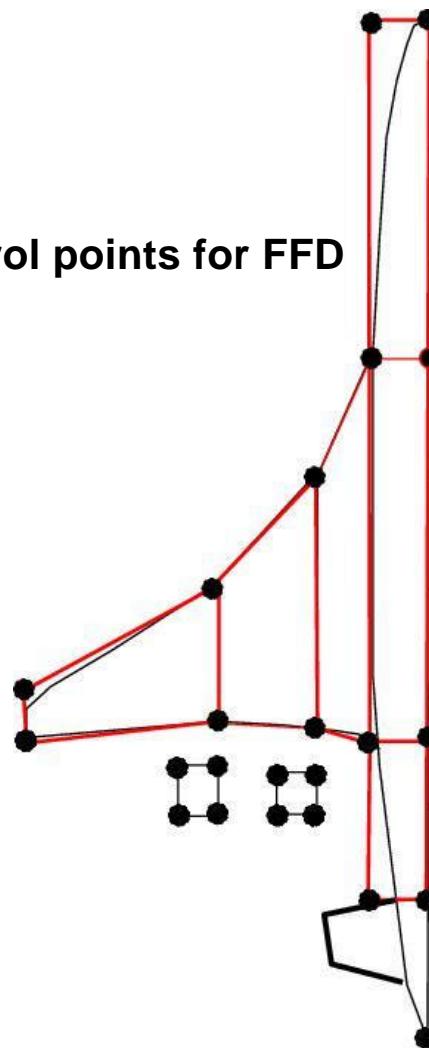
Thickness



Extreme camber & thickness deformation

Planform Parameterization (Free-Form Deformation (FFD))

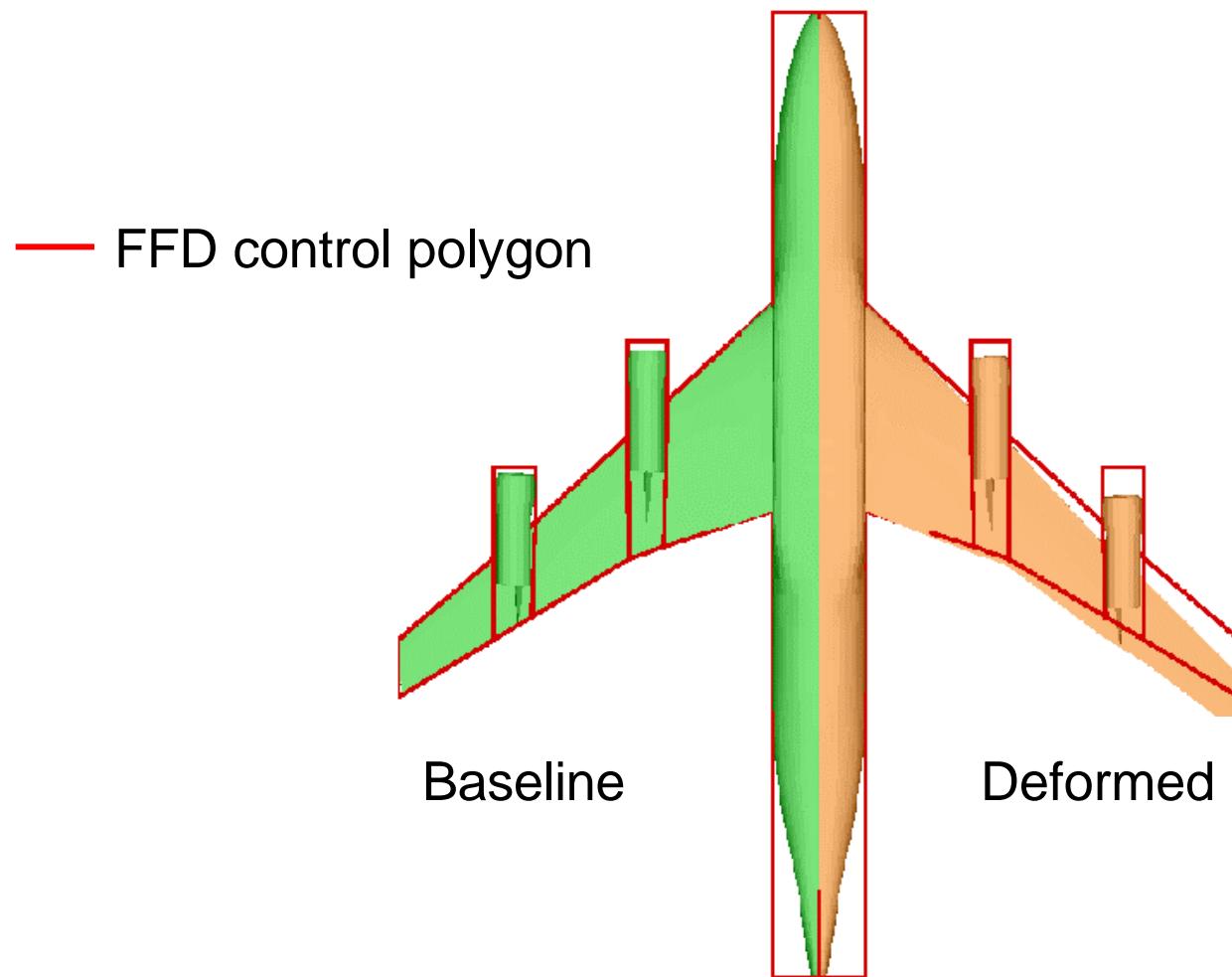
Control points for FFD



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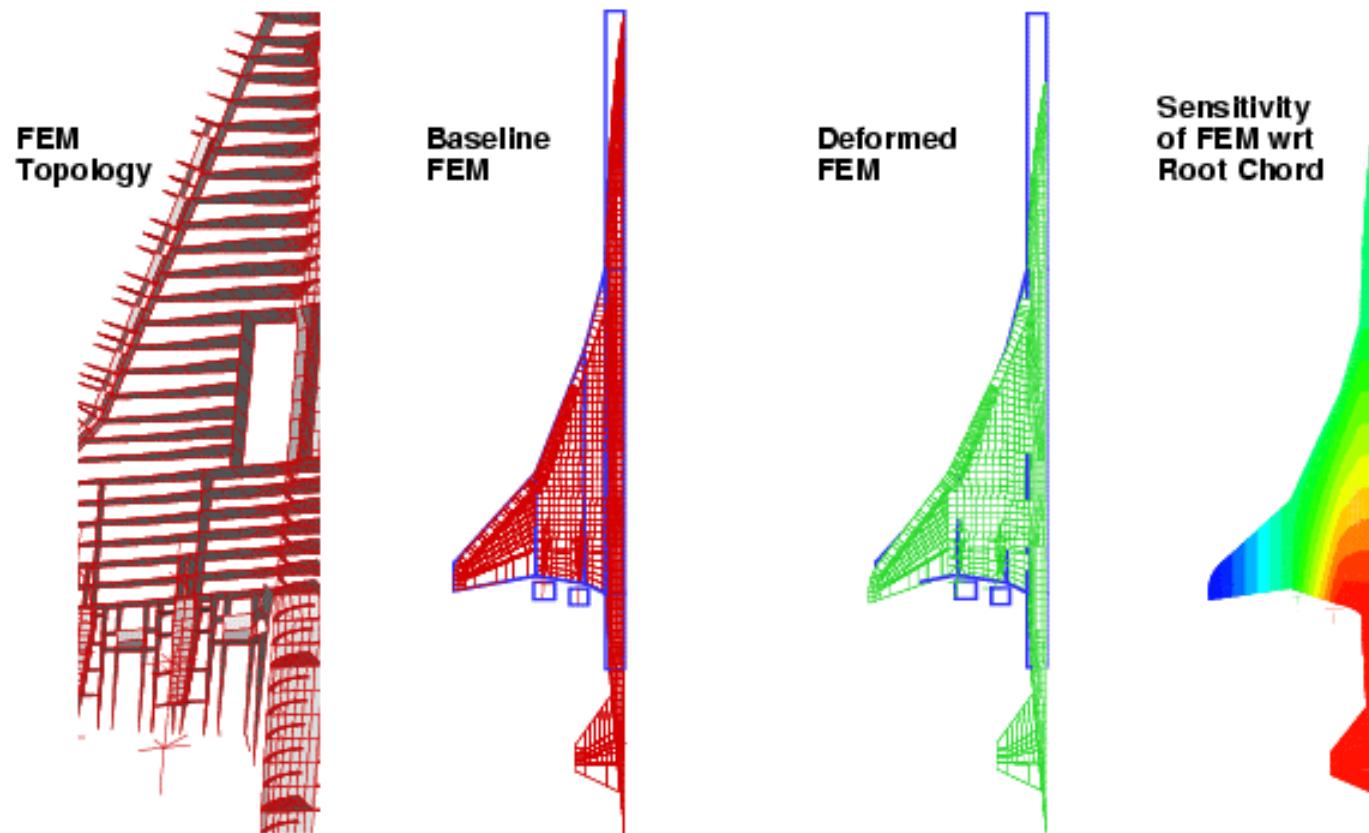
Planform Parameterization (Cont.)

(CFD surface grid of a generic transport)



Multidisciplinary Shape Parameterization of an HSCT Model (FEM)

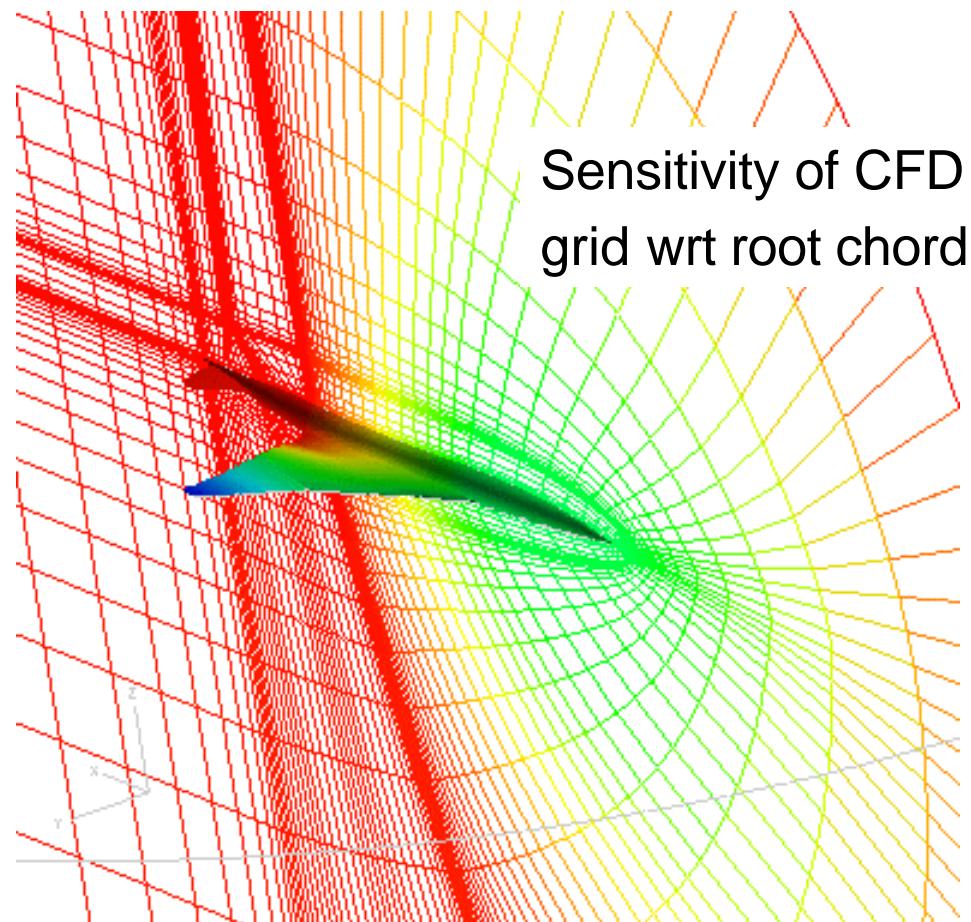
27 design variables



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Multidisciplinary Shape Parameterization of an HSCT Model

(CFD Model)



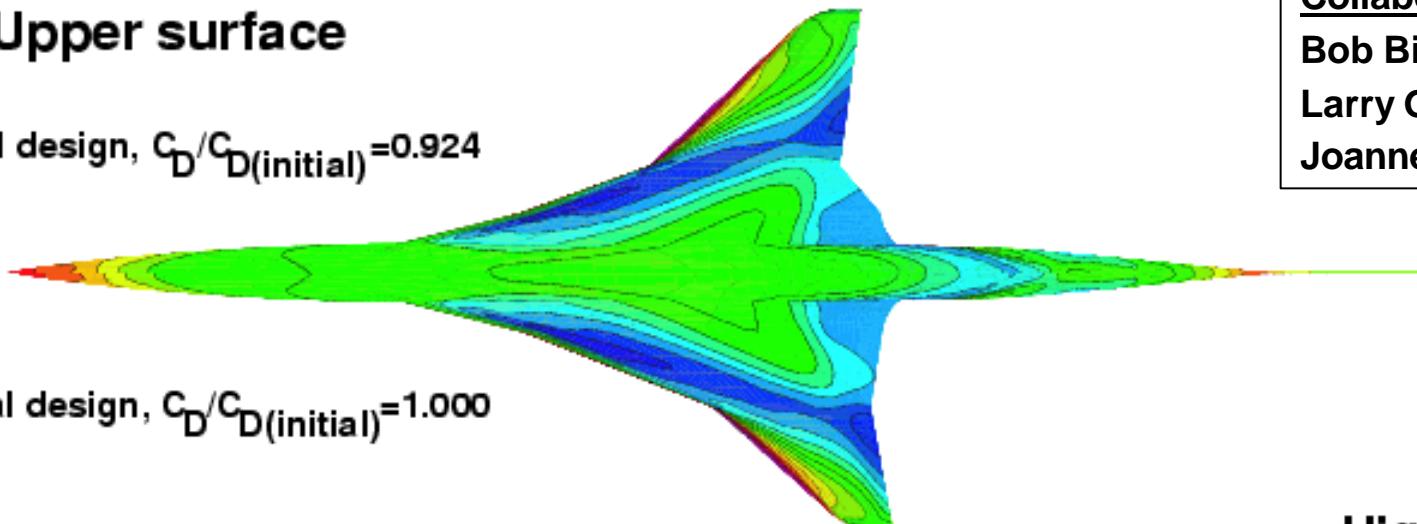
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Nonlinear Aerodynamic Shape Optimization Results

Final design $C_D/C_{D(\text{initial})}=0.924$, Fixed C_L

Upper surface

Final design, $C_D/C_{D(\text{initial})}=0.924$



Collaborators:
Bob Biedron
Larry Green
Joanne Walsh

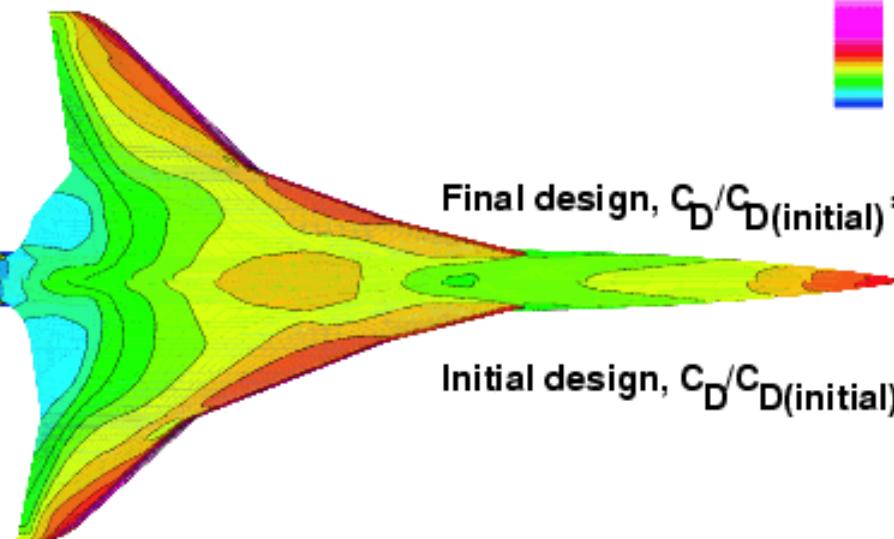
Initial design, $C_D/C_{D(\text{initial})}=1.000$

Lower surface

Final design, $C_D/C_{D(\text{initial})}=0.924$

Initial design, $C_D/C_{D(\text{initial})}=1.000$

High pressure
Low pressure



M6 Aerodynamic Shape Optimization

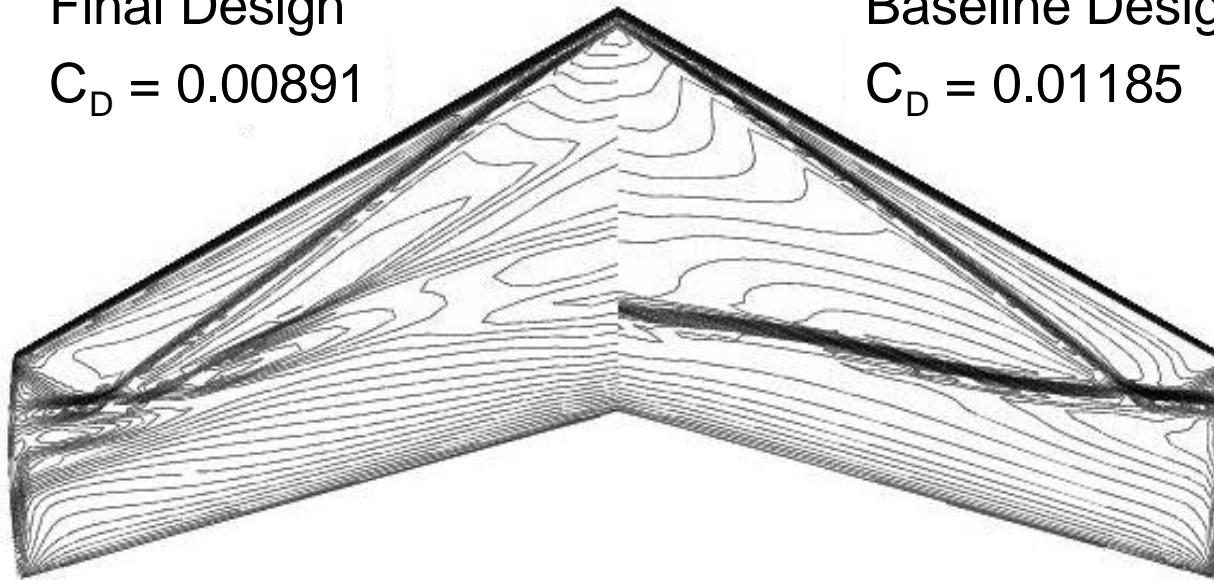
Collaborators:
Bob Biedron
Larry Green
Joanne Walsh

Final Design

$C_D = 0.00891$

Baseline Design

$C_D = 0.01185$



MASSOUD's Pros & Cons

Pros

- Is Consistent
- No need for grid generation
- Easy to setup (hours)
- Parameterization is fast (seconds on OCTANE)
- Analytical sensitivity is available
- Has compact set of DVs
- Suitable for high- and low-fidelity applications

Cons

- Limited to small shape changes
- Fixed topology
- No built-in geometry constraints
- No direct CAD connection

Summary

- Presented a multidisciplinary shape parameterization technique suitable for multidisciplinary shape optimization with high- and low-fidelity analysis tools
- Presented results for multidisciplinary shape parameterization and aerodynamic shape optimization
- MASSOUD is written in ANSI-C and is available for distribution within US

Future Work

- Provide a direct, two-way connection to commercial CAD systems
- Plan to use MASSOUD for MDA and MDO of blended-wing body (BWB) and joined-wing demonstrator